

**BACKGROUND CODE UPDATE
FOR EMBEDDED SYSTEMS**

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention generally relates to embedded systems. More particularly, the present invention is directed to an embedded system and method for performing a background code update by utilizing firmware update routines from an incoming code image and task switching capabilities, i.e., task switching function, from an executing code image.

Description of the Prior Art

An embedded system is a specialized computer system, including both hardware and software, which forms a part of a larger system or machine. Furthermore, the larger system or machine may have a plurality of embedded systems. Typically, each of the embedded systems is housed on single microprocessor board with firmware (i.e., software) stored as object code within a non-volatile memory device, such as a programmable read only memory (i.e., "PROM"). The larger system or machine that generally utilizes the embedded system may include a wide variety of systems, ranging from modems, to mid-range computing devices and enterprise systems, to storage automation libraries, to digital satellite receivers, and the like. The embedded systems commonly utilize firmware that provides an operating system enabling multitasking, which simplifies a process of performing a plurality of actions with a single microprocessor. With multitasking, the microprocessor is utilized more efficiently because the idle time associated with performing one action may be utilized for performing another action. For example, a servo control function may be waiting for a

time interval to elapse (i.e., via a timer) before checking position control parameters of a robotic component of the larger system or machine. While waiting for the timer to expire, the microprocessor may send or receive small computer system interface (i.e., "SCSI") data through another function. These actions are often called processes, threads, tasks, or process threads. Hereinafter, the foregoing actions will be referred to as process threads for simplicity and clarity.

The act of switching between the process threads is called task switching. Task switching based on each process thread voluntarily giving up microprocessor time is commonly referred to as "round robin" task switching. Alternatively, task switching resulting from a resource becoming available or from a function call to signal another process thread (e.g., via sending a message between the two process threads) is commonly referred to as "event driven" task switching. Moreover, task switching based on periodically switching microprocessor control between process threads via a timer or some other trigger is commonly referred to as "time slice" task switching. Additionally, combinations of the foregoing task switching options may be utilized in a particular embedded system. From among the foregoing options, the time slice task switching option tends to be less efficient because a task switch may occur at times other than idle times, thereby wasting processing resources (i.e., unnecessary task switching consumes microprocessor bandwidth). Additionally, time slice task switching is generally more complicated to set up and can create a variety of problems.

Typically, an embedded system provides for a code update process to support new features or to fix problems in the firmware (i.e., firmware upgrade). In many cases, the firmware upgrade will take the larger system or machine--of which the embedded system forms a part--out of service for some period of time during which the firmware upgrade is performed. For the systems which are utilized for critical applications or which are utilized a high percentage of time, it is advantageous to provide a background code update that does not take the larger system out of service. Background updates to the firmware are known in the art. One way the background code update may be achieved is by executing the system code out of memory devices other than those being

upgraded. For example, a system firmware that needs to be updated may reside in a programmable read-only memory (i.e., "PROM") prior to power-up. The system firmware stored on the PROM may be copied to a random access memory (i.e., "RAM") during a power-on sequence and subsequently executed in the RAM. Thus, the system firmware on the PROM may be updated because the current system firmware is executed from the RAM. This is of critical importance because many nonvolatile devices cannot be updated while in use. In addition, overwriting currently executing firmware may result in unpredictable consequences. Therefore, by executing firmware from a separate memory device, a code update to the firmware may occur while the system operates normally utilizing one or more other process threads of the firmware, thereby accomplishing a background code update to the firmware.

Utilizing code update routines from the firmware update itself has associated advantages. A first advantage obtained by utilizing code update routines from the firmware update is elimination of the need to test a newer firmware update against every previous version of firmware that may be present in the field. That is, without utilizing the code update routines from the firmware update, firmware update compatibility between the previous version of the firmware and the newer firmware version may be uncertain and must be tested before attempting an upgrade at a customer site. A further advantage is the whole structure of the previous version of firmware, in PROM, can be updated without any special interim firmware updates at the customer site. For example, the previous firmware installed at the customer site may support a single copy of the firmware in the PROM, while the new version of the firmware may support a boot sector and two copies of the firmware. The update of the previous version of the firmware to the advanced new version that supports the boot sector and the two code copies of the firmware would normally require an intermediate (i.e., "special") code load that would prepare the embedded system for the firmware update because the previous firmware's code update routines have no prior knowledge about the boot sector and the two copies of the new firmware version. If a firmware update were attempted without the special code load, the embedded system and even the larger system of which the embedded system being updated forms a part may become

inoperative. However, the code update routines of the firmware update know all about the details of the firmware update because these routines are part of the new firmware that supports a boot sector and two copies of the firmware. That is, the location of the firmware update routines is provided as part of the new firmware update. The location
5 of the code update routines may be implied as a fixed offset in the new firmware update, or it may be provided as a pointer within the new firmware update. In addition, the code update routines may have a fixed execution point or a variable one. More particularly, 1) the code update routines may be compiled for execution from a particular location in the memory, such that the code update routines are always copied
10 to the particular location in the memory before execution begins; or alternatively 2) the code update routines may be, and usually are, compiled as position independent code, so that they can be executed from any location within memory.

Notwithstanding the foregoing, there exists a problem with executing firmware update
15 routines out of the firmware update. The problem is that function calls cannot be made outside the scope of the firmware update. For example, if the code update routines attempt to call a task switching function that is outside the scope of the update routines, unpredictable results may occur. That is, in order to invoke the task switching function, the new code update routines have to reference a memory map that is disparate from a
20 current memory map associated with the new firmware. For example, assume the first alternative in which the new firmware update is compiled to execute at a base-starting hexadecimal address of 0x0C000000, which happens to be the address of the previous firmware's base-starting execution address after a reset and a copy to RAM. But, the temporary location of the new firmware update will be another hexadecimal address
25 outside the scope of the previous firmware, such as 0xOC100000, because the new firmware update is being received and cannot interfere with or be copied over the previous, currently executing, firmware. Any external address references that the new firmware update routines make will be based on the 0xOC000000 starting hexadecimal address of the new compiled firmware update of which they are a part, but there is no
30 telling what code alignment actually will reside in that space because it contains a version that is different from the previous, currently executing firmware. That is,

elements within the new compiled firmware update may not reside in the same relative position as like elements in the previous firmware, i.e., code in the new firmware update may be shifted either up or down with respect to the previous firmware.

- 5 Now assume the second alternative in which the firmware update is compiled as position independent code. This alternative creates different problems. For example, some microprocessors and compilers do not support position independent code. Additionally, with position independent code, external references are addressed as relative offsets. Therefore, although the new code update routines may include a task
- 10 switching function, the task switching function will have external references to data and code areas, thereby creating problems described hereinabove with regard to the first alternative. For example, a task switching function may be located at hexadecimal address 0x0C080000 of the currently executing firmware. The same task switching function may be located at hexadecimal address 0x0C180340 of the new firmware. An
- 15 attempt, by the new firmware update routines, to call the task switching function will result in a call to the hexadecimal address 0x0C180340. While this address is an accurate location of the task switching function of the new firmware, it may contain references to other memory locations such as a process thread state table. Such references may produce the same unpredictability as described in the previous example
- 20 because the task switching function at hexadecimal address 0x0C080000 is based on another version of the firmware with potentially different address locations or offsets. That is, if the new firmware update is compiled as position independent code, then the task switching function from the new firmware update will attempt to access un-
- 25 initialized code from the new firmware update. If the new firmware update image is compiled for direct addressing of the code, then the task switching function from the new firmware update image will experience the same potential offset problem described in the first alternative. Finally, a change to the task switching function could have unpredictable results if it were to attempt access to a data area initialized by the task switching function that used different data structures.

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Therefore there is a need in the art of a system and method for providing a background
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code update that overcomes the above-identified problems associated with the prior art firmware updates. More particularly, there is a need to provide an embedded system and method that utilizes firmware update routines from the incoming firmware image while utilizing task switching capabilities, i.e., task switching function, from the
5 executing firmware image.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a system and method for an
10 enhanced background code update in an embedded system.

It is another object of the present invention to provide a system and method for performing a background code update in an embedded system by utilizing update routines from the incoming firmware image while utilizing a task switching function
15 from an executing firmware image.

According to an embodiment of the present invention, there is provided a method for performing a background code update of a current code image with an incoming code image in an embedded system, the method comprising the steps of: executing the
20 current code image in the embedded system; executing one or more code update routines from the incoming code image to update the current code image with the incoming code image; and executing a task switching function from the current code image to switch microprocessor control from executing the one or more code update routines of the incoming image to execute a function in the current code image

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According to another embodiment of the present invention, there is provided an embedded system for performing a background code update of a current code image with an incoming code image, the system comprising: a first programmable memory device for storing the current code image; a microprocessor for executing the current
30 code image in the embedded system and for executing the one or more code update routines to update the current code image with the incoming code image; and a task

switching means for executing a task switching function in the current image to switch microprocessor control from executing the one or more code update routines of the incoming image to execute a function in the current code image.

- 5 According to yet another embodiment of the present invention, there is provided a storage automation library comprising an embedded system, the embedded system comprising: a first programmable memory device for storing the current code image; a microprocessor for executing the current code image in the embedded system and for executing the one or more code update routines to update the current code image with
- 10 the incoming code image; and a task switching means for executing a task switching function in the current image to switch microprocessor control from executing the one or more code update routines of the incoming image to execute a function in the current code image.
- 15 According to further embodiment of the present invention, there is provided a program storage device, tangibly embodying a program of instructions executable by a machine to perform a method for performing a background code update of a current code image with an incoming code image in an embedded system, the method comprising the steps of: executing the current code image in the embedded system; executing one or more
- 20 code update routines from the incoming code image to update the current code image with the incoming code image; and executing a task switching function from the current code image to switch microprocessor control from executing the one or more code update routines of the incoming image to execute a function in the current code image.
- 25 According to yet a further embodiment of the present invention, there is provided a method for performing a background code update of a current code image with an incoming code image in an embedded system, the method comprising the steps of: executing the current code image in the embedded system; retrieving an offset from the incoming code image of one or more code update routines in the incoming code image;
- 30 executing the one or more code update routines to update the current code image with the incoming code image; retrieving an offset from the current code image of a task

switching function upon a task switching event; and executing the task switching function to switch microprocessor control from executing the one or more code update routines of the incoming image to execute a function in the current code image.

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BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features and advantages of the present invention will become apparent to one skilled in the art, in view of the following detailed description taken in combination with the attached drawings, in which:

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Figure 1 is an exemplary block diagram of a suitable embedded system that may be utilized to practice the exemplary method of Figure 3 according to the present invention;

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Figure 2 is an exemplary detailed block diagram of a flash PROM map for the flash PROM illustrated in Figure 1 according to the present invention;

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Figure 3 is an exemplary method flow chart illustrating execution of a background firmware update utilizing code update routines from an incoming code image and a task switching function from a currently executing code image according to the present invention;

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Figure 4 is an exemplary frame of a storage automation library that utilizes a plurality of embedded systems each of which is upgradable via the background code update that utilizes firmware update routines from an incoming code image and a task switching function from an executing code image according to the present invention; and

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Figure 5 is an exemplary overview representation an L-frame that houses the exemplary frame of Figure 4 according to the present invention.

**DETAILED DESCRIPTION OF THE
PREFERRED EMBODIMENT OF THE INVENTION**

The present invention is directed to a system and method for providing a background
5 code update that overcomes the above-identified limitations associated with the prior art
firmware updates. More particularly, the present invention provides an embedded
system and method that utilizes firmware update routines from the incoming firmware
image while utilizing a task switching capabilities, i.e., task switching function, from
the firmware being updated. It is noted that hereinafter a task switching function
10 represents a collection of executable computer instructions and not necessarily a
call/return relationship. Therefore, it should be understood that the task switching
function may comprise one or more functions for achieving the task switching
capabilities.

15 Figure 1 is an exemplary block diagram of an embedded system 100 according to the
present invention. The embedded system 100 of Figure 1 comprises the following
system components: device specific circuits 102; a microprocessor 104; a random
access memory (i.e., "RAM") 106; nonvolatile memory device such as a flash
programmable read only memory (i.e., "PROM") 108; an input/output interface (i.e.,
20 "I/O") 110; and a bus 112 that interconnects the foregoing system components. It is
contemplated that different combinations of the foregoing system components as well
as other components not shown in Figure 1--e.g., real-time clock, digital to analog
converter (i.e., "DAC") and analog to digital converter (i.e., "ADC")--may be integrated
into the microprocessor 104, thereby forming an integrated microprocessor 104. For
25 example, it is preferable to integrate the RAM 106 and the flash PROM 108 into the
microprocessor 104. Alternatively, the RAM 106 and the PROM 108 may be combined
in a single device, such as a battery backup RAM (not shown). It should be noted that
the integration may achieve space/cost savings and/or greater processing speeds.
Notwithstanding the component integration issue, the microprocessor will simply be
30 referred to as the microprocessor 104. It is further also contemplated that the embedded
system 100 may comprise more than one microprocessor 104 (not shown). The I/O

interface 110 represents a communication interface that enables the microprocessor 104 to communicate with devices or systems that are external to the embedded system 100, such as another component of the overall system or an external host computer. The I/O interface 110 may include a plurality of different serial interfaces, such as versions of the Recommended Standard RS-232 (e.g., RS-422 and RS-423), Universal Serial Bus (i.e., "USB"), Institute of Electrical and Electronics Engineers 1394 standard (i.e., "IEEE 1394") that is trademarked, among other things, as "FireWire" by Apple, Controller Area Network (i.e., "CAN"), Ethernet, Small Computer System Interface (i.e., "SCSI"), Fibre Channel and the like. It is also contemplated that the I/O interface 110 may include wireless communication standards, such as radio frequency (i.e., "RF"), satellite, optical and the like.

According to the present invention, a firmware update is transmitted into the embedded system 100 via the I/O interface 110. The firmware update (i.e., incoming code image) may be transmitted from another microprocessor 104 in the embedded system (assuming more than one microprocessor 104), from an attached personal computer (i.e., "PC"), a remote PC through a wireless link, a modem and the like. The device specific circuits 102 provide additional hardware to enable the embedded system to perform unique functions. Examples of the unique functions may include motor control of robotic grippers for an automated data storage library as particularly illustrated in Figure 4 below. However, the embedded system 100 of the present invention is not limited to the particular application illustrated in Figure 4 and may be embedded in a wide variety of systems. While the foregoing description makes reference to flash PROM 108, it should be noted that various nonvolatile memory devices may be used in the present invention. The various nonvolatile memory devices may include battery backup RAM; electronically erasable PROM (i.e., "EEPROM"); magnetic storage, such as, a hard drive or a floppy drive; optical storage, such as, Magneto Optical (i.e., "MO"); and the like. In addition, more than one nonvolatile memory device may be present in the embedded system 100.

Figure 2 is an exemplary detailed block diagram of a flash PROM map 200 for the flash PROM 108 of Figure 1, which comprises a boot sector 202 and a code image 204. The boot sector 202 includes firmware (i.e., often referred to as a “bootloader”) that is executed at boot-up time and is utilized as a failsafe for a corrupted code image 204.

5 That is, the bootloader in the boot sector 202 is executed at boot up time, in turn testing the integrity of the code image 204--preferably by computing a checksum and comparing it with a stored result or predetermined value--before actually executing the code image. The bootloader may further diagnose whether the code image 204 is corrupt and enable update of the code image if it is corrupt. If the bootloader detects an integrity error, it can use the I/O 110 to receive a firmware replacement. Alternatively, a backup code image may be provided so that a failed integrity test of the code image 204 results in the execution of the backup code image. The backup code image may be provided in another flash PROM 108 or may be stored separately from the code image 204 on the same flash PROM 108.

15 Now further referring to Figure 2, the code image 204 includes a header area 206, a vital product data area (i.e., “VPD”) 208, and an executable code and data area 210. The header stores information about the code image 204. The VPD area 208 stores unique product information that must be preserved through a power cycle of the embedded system 100, i.e., the product information stored in the VPD area 208 must not be lost as a result of powering off the embedded system or performing a background code update according to the present invention. The unique product information may include a variety of identification numbers (e.g., serial number), configuration settings, and the like. The executable code and data area 210 includes the compiled and linked code image, i.e., the previous firmware image that is executed prior to being updated with an incoming firmware image according to the present invention, as particularly illustrated in Figure 3 below. The compiled and linked code image forms an output of a firmware build process, which is generally a part of product development at a manufacturing site. It should be noted that the header area 206 and/or VPD area 208 may form a part of the executable code and data area 210 as elucidated below.

30 Alternatively, the header area 206 and/or VPD area 208 may not be present at all. The

header area 206 is not required for the invention, but it makes the code image 204 more flexible. In addition, the boot sector 202 may likewise form a part of the code image 204.

5 The header area 206 includes a plurality of header fields 211, which include a header size 212, a code version 214 of the code image 204, an offset for the code update routines 216 in the code image 204, an offset for the task switching routines 218 in the code image 204, and two spare pointer fields 220 and 222. The spare pointer fields 220 and 222 facilitate future enhancements in the embedded system 100 that may take
10 advantage of the header area. For example, a future firmware upgrade may require a pointer to an area in the code image 204 and the spare pointer fields 220 and 222 would provide this enhancement. That is, the spare fields 220 and 222 may be used to point to new features in the code image 204 and testing these pointer fields (i.e., for a valid address or NULL) may provide information regarding whether or not the code image
15 204 supports the new features. It should be noted that the foregoing list of fields 211 in the header area 206 is only exemplary and therefore the header area 206 is not limited to these particular fields. As mentioned above, the header area 206 may completely be eliminated by storing the header fields 211 at predetermined locations within the code image 204. That is, the offsets (e.g., code update routine offset 216 and task switching
20 routine offset 218) may be present in the code image 204 at predetermined locations but not part of a formal structure in the header area 206.

Figure 3 is an exemplary method flow chart illustrating a background firmware update 300 of an executing code image 301 with an incoming code image 303 according to the
25 present invention. As aforementioned regarding the fact that the boot sector 202 may form a part of the executing image 301, the boot sector 302 may likewise form a part of the incoming image 303. It is preferable that the boot sectors 202 and 302 form a part of their respective code images 301 and 303, so that the boot sectors may be upgraded via the background code update according to the present invention. It should further be
30 noted that all or part of the incoming code image 303 is first loaded into the RAM 106 of the embedded system 100 depicted in Figure 1, which enables the microprocessor TUC920010094US1

104 to execute the code update routines from the incoming code image 303.

Subsequently, the code update routines are executed from the RAM 106 to rewrite the flash PROM 108 with the updated firmware from the firmware update transmitted via the I/O interface 110. In order to mitigate the problem of the task switching function switching to a function in the executing code image 301 while it is being overwritten by the firmware update 300, which may result in an unpredictable outcome, it is contemplated that two separate code areas that include copies of the firmware to be updated are provided in the embedded system 100, so that that the process threads being executed are not overwritten by the firmware update 300. In a first alternative, the two separate code areas represent two flash PROMs 108, where the copy of the firmware on one memory device is updated while the copy of the firmware on the other memory device is executing. That is, two flash PROM modules 108 may be provided in the embedded system 100, wherein the code update routines are executed from one of the flash PROM 108 while the other flash PROM 108 is rewritten, i.e., updated with the firmware update transmitted via the I/O interface 110. In another alternative, the two separate code areas may both be stored on a single nonvolatile memory device, which allows reading the nonvolatile memory device during update. An exemplary nonvolatile memory device that allows alternate read/write is a battery backup RAM disclosed herein. Thus, with two code images, one code image may be executed while the other code image is updated. Still further, in another alternative, the current firmware is copied from the flash PROM 108 to RAM 106 after a power-on or reset, and the flash PROM 108 is overwritten by the new firmware since current firmware resides in the RAM 106.

Now particularly referring to the method of Figure 3, at some point in time prior to step A, the embedded system 100 is functioning in a normal manner and a background code update according to the present invention is initiated through the I/O interface 110.

Thereafter, at step A, the microprocessor 104 executes the executable code 210 of the previous firmware image 301, which accesses the code update routines offset 316 of the incoming code image 303. At step B, the offset of the new code update routine 316 in the incoming code image 303 is retrieved by the executable code 210 of executing code

image 301 from the header area 304 of the incoming code image 303. At step C, microprocessor control is transferred from the executing code image 301 to the incoming code image 303, i.e., executing the new code update routines from the executable code and data 310 as pointed to by the code update routine offset 316. At a later point in time, the new code update routines yield microprocessor control to any other process thread via any of the aforementioned task switching methods (e.g., time slice, event driven, round robin or a combination thereof). Notwithstanding the applicability of the present invention to the entire foregoing task switching methods, the present invention is particularly applicable to round robin method in which each process thread voluntarily gives up microprocessor control. More particularly, in order to switch to a different process thread, a task switching function is to be utilized. Therefore, at step D the new code update routines of the executable code and data 310 in the incoming code image 303 retrieve the task switching routine offset 218 from the header area 206 of the executing code image 301. Thereafter at step E, microprocessor control is thus transferred to the task switching function in the executable code and data 210, which switches microprocessor control to any other process thread, i.e., effectively executing the other process thread from the executing code image 301. Task switching is performed by a part of an operating system (not shown) of the embedded system 100, which is generally called a scheduler (not shown). The scheduler makes decisions about which process thread is to receive control of the microprocessor 104 based on process thread priorities and available resources (e.g., memory and messages) and the like. At still a later point in time, the other executing process thread yields microprocessor control. It is noted that the microprocessor control may be switched several times to various process threads within the executable code and data 210 before, at step F, the microprocessor control is eventually switched back to the new code update routines in the executable code and data 310 of the incoming code image 303.

Further with reference to Figure 3, the foregoing control task switching is repeated until the code update process completes, which updates the executing code image 301 with the incoming code image 303. It should be noted that the task switching may be performed from and to various processes threads. The process threads may include any

process threads involved in normal operations of the embedded system 100, such as process threads that provide robotic control, communications and the like. After completion of the update, the embedded system may begin execution of the newly updated firmware, i.e., firmware written to the flash PROM 108, in the embedded system 100. This may be accomplished via a branch or a jump instruction to a flash PROM address, or a function call to the flash PROM address. Alternatively, the microprocessor 104 may begin execution of the updated firmware via a reset of the embedded system 100. The reset may be accomplished through firmware control, power off and the like. The reset may further be initiated by the overall system that comprises the microprocessor 104, by another component of the overall system (e.g., another embedded processor), by an operator, or by a device that transmitted the incoming firmware image via I/O interface 110 to the embedded system 100.

As particularly described above, the exemplary method enables a background code update in an embedded system by utilizing the code update routines from the incoming code image and a task switching function from the executing code image. In a further preferred embodiment, one or both of the firmware images (i.e., the executing and the incoming code images) include pointers to any required functions. For example, there may be pointers to a task switching function and code update routines. More particularly, the firmware images 301 and 303 may have header areas, such as 206 and 304 respectively, where these pointers are defined as 216, 316 and 218, 318 for the task switching function and code update routines respectively. Optionally, these pointers may be located at predefined locations in the code image. Thus, when a code update begins, by utilizing the pointers in the incoming code image 303 for the code update 316, the code update routines are executed out of the incoming code image 303, i.e., from the executable code and data 310 of the incoming code image 303. These code update routines will look at the currently executing code image, loaded in the flash PROM 108 or RAM 106 of the embedded system 100 to identify where the task switching function is really located in the executing code image 301. Still further, there may not be any pointers at all, in which case the code update routines and/or task switching function would reside at predetermined locations in the respective code

images. Therefore, what has been described in detail herein is a novel system and method for enabling task switching to occur while providing the necessary background code update process.

- 5 Figure 4 is an exemplary frame 400 of a storage automation library that utilizes a plurality embedded systems of Figure 1, the firmware of which is upgradable via the background code update that utilizes firmware update routines from an incoming code image and a task switching function from an executing code image, according to the present invention as particularly illustrated with regard to Figures 1-3. The exemplary
- 10 frame 400 is all or part of an automation library, i.e., IBM's Ultra Scalable Tape Library 3584. The frame 400 comprises an Accessor assembly 401, which includes a gripper assembly 402 and an XY assembly 404; and a front door (i.e., reference 508 depicted in Figure 5 below) that includes the operator panel assembly 406 and one or two import/export I/O stations (i.e., references 512 and 514 depicted in Figure 5 below).
- 15 The I/O stations are utilized for operator input/output of removable media.

The frame 400 may comprise one to twelve drives 422. The drives may be any combination of small computer system interfaces, such as SCSI LVD, SCSI HVD, and Fibre Channel-Arbitrated Loop. The drives are coupled via interfaces 426 to the

20 Medium Change Controller (i.e., "MCC") card 416 for enabling the storage automation library to communicate with drives 422. Interface 426 may comprise any serial interface known to those skilled in the art. The communication from the storage automation library to host 420 travels through the same connection, i.e., interface 426.

- 25 The MCC card 416 also includes a diagnostic interface 432, a 10/100 Ethernet interface 430, a modem interface 428 for connecting to a modem, circuits to control the DC power in the library 436, and frame counting circuits 434 for a multi-frame automation library. The diagnostic interface 432 utilizes a protocol and a command structure and is used by repair personnel. The 10/100 Ethernet interface 430 provides Simple Network
- 30 Management Protocol (i.e., "SNMP") support and Hyper Text Transfer Protocol (i.e., HTTP) support. The modem interface enables the automation library to initiate a call
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to a repair center for help (i.e., via "Call Home") and it also enables the repair center to call the library (i.e., via "Call In"). The MCC card 416 monitors and controls the DC power and the DC power supply fans through power control circuits 436. The frame counting circuits 434 count the number of frames in the multi-frame automation library.

- 5 With the frame counting circuits 434, the MCC card 416 can tell which frame number it is connected to as well as any doors that may be open in any frame.

- The MCC card 416 communicates to the Accessor Controller card (i.e., "ACC") 410; the XY Controller (i.e., "XYC") card 412, the Operator Panel Controller (i.e., "OPC") card 414, and any other frame cards that may be installed in the automation library. A Controller Area Network (i.e., "CAN") 418 interface provides communication between the cards 410, 412, 414 and 416 in the automation library. The CAN is a multi-drop network interface, which although designed originally for the automotive industry, has gained wide acceptance in the industrial control industry and is currently utilized in the storage automation library according to the present invention. It should be noted that the CAN interface preferably comprises two CAN busses, one for primary communication and one for redundant operation in an event of a failure of the primary CAN bus.

- 20 The Accessor assembly 401 includes a XY rail assembly 404, which comprises an XY motion control card 412 and motors (not shown). The Accessor assembly further includes a gripper assembly 402, which comprises a dual gripper motion control card 410 and motors (not shown). The XY rail assembly 404 moves back and forth along a length of the automation library on the X rail (i.e., reference 530 depicted in Figure 5 below). The gripper assembly 402 moves up and down the Y rail (i.e., reference 532 depicted in Figure 5 below) under control of the XY assembly 404. The gripper assembly 402 further comprises a bar code scanner 403 for reading cartridge labels and preferably includes a smart card reader for reading an electronic cartridge memory inside an LTO cartridge (not shown). The gripper assembly 402 still further comprises two grippers 405 for mixed media support, i.e., two different media types in a single automation library. Alternatively, the gripper assembly may comprise a redundant
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gripper for a single media type. The grippers are mounted in a cage that can pivot from one side of the library to the other via a pivot mechanism 407. This allows access to both walls of storage by either of the grippers 405.

- 5 The operator panel 406 includes an LCD display (preferably of high-resolution) 409, a touch screen for user input 411, a frame counter 415 (like the frame counter 434 of the MCC card 416), and sensor circuits 413 to monitor and control the I/O station doors. That is, the sensors circuits 413 monitor the state of the doors, such as opened, closed, or locked. The I/O station doors are manually opened and closed by an operator. Lock mechanisms are controlled by the OPC card 414 and will prevent a user from opening a
- 10 I/O station door. The upper I/O station (i.e., reference 512 depicted in Figure 5 below) is required. The lower I/O station (i.e., reference 514 depicted in Figure 5 below) is optional.
- 15 The following describes the background code update of the MCC 416 embedded system, in frame 400 of the storage automation library according to the present invention. It should be noted that the firmware of the other embedded systems, i.e., 410, 412 and 414, may be similarly updated as described below. In normal operation, the MCC 416 of the storage automation library moves storage cartridges between
- 20 storage slots (depicted in Figure 5 below) and LTO drives, as requested by each host system 420. A request to update the storage automation library firmware is transmitted through the diagnostic port 432 or is transmitted from a host computer 420 through interface 426. The update request may be in the form of a proprietary command and protocol, or may be a common command and protocol such as the SCSI Write Buffer
- 25 command. During the firmware update, the MCC 416 receives the incoming code image via its I/O interface 110 and writes the incoming code image to the flash PROM 108 while performing other MCC tasks such as drive communication, serving web pages from the Ethernet port 430, and the like. Each ACC card 410, XYC card 412 and OPC card 414 comprises a respective flash PROM memory 108, which is updated with
- 30 the newest firmware in a similar fashion while performing respective storage automation library operational tasks, such as XY motion, gripping and releasing
- TUC920010094US1

cartridges, handling operator input from a panel display, and the like. Furthermore, each of these cards 410, 412, 414 and 416 task switches between normal library operations and the code update operations according to the present invention.

5 Figure 5 is an exemplary representation of L-frame 500 of the frame 400 of Figure 4 according to the present invention. The L-frame 500 is depicted with a front door 508 that is open. The housing of the L-frame 500 comprises front door 508, top panel 502, side panels 518, and back panel 520. Storage slots 504 are utilized to hold cartridges (not shown) to be utilized in the LTO drives 422. As aforementioned with reference to
10 Figure 4, the L-frame 500 may comprise up to 12 LTO drives 422. The L-frame 500 further comprises a door switch 510 for locking the front door 508. The I/O stations 512 and 514 provide the I/O interface to the frame 400. The operator panel assembly 406 provides a touch screen for user input as aforementioned with reference to Figure 4. Further as mentioned above with reference to Figure 4, the Accessor assembly 401
15 includes the XY rail assembly 404, which comprises the XY motion control card 412. The XY rail assembly 404 moves back and forth along a length of the automation library on the X rail 530. The gripper assembly 402 moves up and down the Y rail 532 under control of the XY assembly 404. The Accessor assembly 401 further includes a gripper assembly 402, which comprises the ACC card 410, the bar code scanner 403 for
20 reading cartridge labels, and preferably a smart card reader for reading an electronic cartridge memory (not shown) inside the cartridge (not shown). As aforementioned with reference to Figure 4, the gripper assembly 402 comprises two grippers 405 for mixed media support or a redundant gripper for a single media type. The grippers 405 are mounted in a cage that can pivot from one side of the library to the other via a pivot
25 mechanism 407.

While the invention has been particularly shown and described with regard to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing
30 from the spirit and scope of the invention.